Contract Number W9132T-04-C-0017

ReliOn, Inc.

Final Project Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY03

Telecom PBX Switch
Gabreski Air National Guard Base
Westhampton Beach, New York

August 31, 2006

Executive Summary

The CERL fuel cell installation at Gabreski Air National Guard Base (ANGB), Long Island, New York is one of three ReliOn demonstration sites funded under the BAA-FY03 program (CERL3). The other ReliOn demonstration sites are at Ft. Rucker, Alabama (3 units at 1 kW each and 1 unit at 2 kW) and Ft. Lewis, Washington (4 units at 1 kW each).

This project tested the reliability of the ReliOn backup power solution for a U.S. military base communication system. The ReliOn 4 kW Fuel Cell System provided backup power to the telephone PBX switch & peripheral equipment located in the communications equipment room in Building 250 at Gabreski ANG. The ReliOn fuel cell supplied power at 48 VDC. The fuel cells were connected to the 48 V battery string on a new uninterruptible power supply (UPS) system installed for this project. The fuel cell systems were configured to monitor the commercial AC power grid as well as the status of the DC batteries on the UPS rack. Upon loss or failure of either power source, the fuel cells were designed to start automatically to provide up to 48 kWh of continuous run power to critical equipment at each site. In addition to providing continuous protection from a primary power failure, the installation was designed to simulate a power failure in the AC grid each day. Data was collected concerning start-up times, power availability, shutdown capability, system efficiencies, load following, and the effects of varying environmental conditions. If the system failed to start up properly or provide required power to the load, this was noted in the logs as a failure and counted against the target 90% reliability and availability of the system.

Through the end of the 1-year test program, there were 369 starts and 372.1 hours of run time. In addition to the daily test runs, the ReliOn Fuel Cell systems at these sites maintained critical equipment functionality over 4 primary power outages totaling 4 hours during the demonstration period. According to CERL reporting requirements, overall reliability and availability calculations in this project have been based on total system performance, including special test equipment (computers, modems, PLC controllers) that is not part of ReliOn's commercial fuel cell product line. Availability calculations are also impacted by missed fuel deliveries if vendor scheduling or site access issues result in depletion of fuel reserves. Such incidents were very infrequent over the 1-year demonstration period. When they have occurred, the fuel cells started on command but were unable to sustain energy delivery to the load, resulting in automatic reconnection of the site rectifier. On this basis, cumulative reliability for the demonstration program at Gabreski was 97.6% and cumulative availability was 97.3 percent. When fuel supply interruptions are removed from the calculations, reliability and availability of the commercial fuel cell equipment were both at 100% over the entire 1-year demonstration period.

At the conclusion of the demonstration test program, the fuel cell system was converted to commercial configuration by removal of special test control and monitoring equipment. Ownership and operation of the system has been turned over to the host and it remains on standby status to protect critical communication equipment at the site.

Table of Contents

1.0 Descriptive Title

A demonstration of modular proton exchange membrane (PEM) fuel cells to serve as back up power for mission critical loads – ILS and other communication systems.

2.0 Name, Address and Related Company Information

ReliOn, Inc.	DUNS #: 137264193
15913 East Euclid	CAGE Code: 3K7Y7
Spokane, WA 99216	TIN: 912191190
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Fax:	(509) 228-6510

ReliOn, Inc., a privately held, small business, headquartered in Spokane, Washington, manufactures and markets proton exchange membrane (PEM) fuel cell products based on a unique and patented modular design. The company's current focus is on the sale and installation of highly reliable backup power solutions for critical applications within the telecom, utility and government/military markets.

ReliOn's offering helps customers increase network reliability while reducing overall equipment life-cycle costs in stationary, low power applications, typically requiring 200 watts to 12 kilowatts. ReliOn designs and supplies highly reliable air-cooled, self-hydrating fuel cells that require minimal balance of plant. The ReliOn system is able to bypass potential failure points often present in competing technologies.

ReliOn, formerly Avista Labs, has been developing, demonstrating and marketing PEM fuel cell technology since 1995.

3.0 Production Capability of the Manufacturer

ReliOn, Inc., as described above, was the manufacturer and integrator of the primary products that comprised the backup power solution. These products incorporate the I-1000™, 1kW fuel cell systems, and the Outdoor Enclosure System which is designed to house the fuel cells, hydrogen fuel and fuel delivery system. ReliOn was responsible for installation and commissioning of the backup power solutions and performed all maintenance requirements via company applications engineers.

The I-1000™ Fuel Cell models and Outdoor Enclosure Systems are commercially available and offered under full warranty terms. ReliOn is currently (mid-2006) releasing its next generation fuel cell systems—the T-1000™ and T-2000™ products—which are substantially based on the I-1000™ product line. Until the end of 2004, ReliOn produced the I-1000™ product line through its contract manufacturer, Celestica, with production facilities in Fort Collins, Colorado. The fuel cell systems installed in this project were manufactured by Celestica. ReliOn currently has two contract manufacturers—Servatron producing circuit boards and control system subassemblies, and Logan Industries for final fuel cell assembly and integration into the Outdoor Enclosure system. Both of these firms are located within a 3 mile radius of ReliOn headquarters in Spokane, Washington, allowing easy interface and rapid problem solving. Production totaled approximately 500 I-1000™ fuel cells and 250 Outdoor Enclosure systems in 2005. With the release of the T-1000™ and T-2000™ products, these outputs are on track to double in 2006.

ReliOn's fuel cells are made from common materials using mature manufacturing processes in injection molded plastic, sheet metal fabrication and printed circuit board assembly. The membrane electrode assemblies (MEA) are purchased through a supply agreement with 3M.

4.0 Principal Investigator(s)

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Mr. Russell Neff
Application Engineer
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5.0 Authorized Negotiator(s)

Mr. Frank A. Ignazzitto
Vice President, Government Sales
ReliOn
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fignazzitto@relion-inc.com

6.0 Past Relevant Performance Information

ReliOn currently (mid-2006) has more than 200 fuel cell systems installed and operational in commercial applications covering 4 continents. Our fuel cell systems and backup power solutions have achieved numerous safety and performance certifications including; CSA, CE and NEBS Level III (telecom).

ReliOn's experience is inclusive of the following installations:

- **The Federal Aviation Administration;**
  - Palwaukee, IL, Radio Transmitter Receiver, December, 2003

- Swinns Valley, WI, Microwave, June, 2004
- Wakeman, OH, Microwave, August, 2004
- Fargo, ND, RCAG, September, 2004
- Average turn-key cost was approximately $35,000
- Contacts: Mr. Stanley Lee, General Engineer, 847-294-8457; stanley.lee@faa.gov
  Mr. Steve Aldridge, Environmental Engineer, 952-997-9264; steve.aldridge@faa.gov

- **The Bureau of Reclamation;**
  - Loveland, CO, Microwave, October, 2003
  - System cost was approximately $15,000
  - Contact: Mr. Nathan Myers, Electrical Engineer, 303-445-2633 nmyers@do.usbr.gov

- **The States of Maryland and Ohio;**
  - 2 Sites in MD, 4 Sites in OH
  - E-911 radio equipment, August 2003 to October, 2004
  - Average turn-key cost was approximately $30,000 (no outdoor enclosure)
  - Contact: Mr. George Milne, COO, havePOWER, 202-299-0506 gmilne@havepower.com

7.0 Host Facility Information

Gabreski Air National Guard Base is the home of the 106th Rescue Wing. The 106th Rescue Wing, New York Air National Guard, is the parent organization of the Oldest Air National Guard unit in the Country—the 102nd Rescue Squadron. The 102nd Rescue Squadron traces its roots back to the 1st Aero Squadron which was formed in 1908 in New York.

The peacetime mission of the 106th Rescue Wing is two-fold. Firstly, it is tasked with conducting Search and Rescue (SAR) and Medevac Operations in an area delineated from the Northeast United States, south to the Bahama Islands and east to the Azores. The unit is able to provide long range rescue due to its air refueling capability. A rescue operation is illustrated in Figure 1. Secondly, the 106th Rescue Wing provides the Airborne Mission Commander (AIRBOSS) for every shuttle launch, as well as pararescuemen on board the HC-130 for deployment in the event of a Mode VIII event. Pararescue Jumpers are occasionally deployed to overseas locations during the launch to provide support to the Air Force. In addition to it's primary mission, the 106th RQW is tasked by the New Hampshire Fish and Wildlife Service with conducting extensive mountain search support.

The 106th is located in Westhampton Beach, Long Island, New York, which is approximately 80 miles east of New York City. The unit occupies one half of the Suffolk

County airport named after Colonel Francis S. Gabreski, the leading living ace of World War II and Korea.

Key contact personnel at the host site were as follows:

CMSgt Stephen Thorenz	LTC Jerry Webb
Voice: (631) 288-7475	Voice: (631) 288-7470
Fax: (631) 288-7599	Fax: (631) 288-7599
Email: Stephen.Thorenz@NYSUFF.ang.af.mil	Email: Jerry.Webb@NYSUFF.ang.af.mil

The project at Gabreski ANGB consisted of a backup power solution for the base telephone PBX switch and peripheral equipment. The telecom equipment is located in the 106th Communications Squadron Headquarters, Building 250 as pictured in Figure 2. The site utilizes four (4) ReliOn I-1000 (1kW) fuel cells connected in parallel as a 4 kW source of backup power. The four fuel cell systems are housed in an outdoor enclosure installed just outside of Building 250. The fuel cell installation in the enclosure is shown in Figure 3.

Pavehawk lifts a Rescue Jumper and the downed pilot he "saved". *Photo by Walt Wheeler*

Figure 1. 106th Rescue Wing Operation At Sea

Figure 2. 106th Rescue Wing Headquarters
Gabreski ANGB

Figure 3. Fuel Cells Installed in ReliOn Outdoor Enclosure System at 106th Rescue Wing Headquarters Building

8.0 Fuel Cell Installation

The ReliOn Fuel Cell Outdoor Enclosure is a self-contained, turn-key system that is delivered to the site ready to set on the concrete pad and wire in to AC and DC circuits. System monitoring, data acquisition, and control are accomplished through Ethernet, analogue telephone (POTS), or discrete signal contacts, depending on configuration. The Scope of Work was supplied by ReliOn to the general contractor for installation of the fuel cell systems at Gabreski ANGB including all power wiring and signal and control interconnection is given in Appendix 1. Installation drawings for the four fuel cell installation sites at Gabreski ANGB are included in Appendix 2.

The 4-kW fuel cell power system was installed adjacent to Building 250 at Gabreski ANGB. As part of this project, ReliOn specified and installed a new telecom uninterruptible power supply (UPS) system that functions in parallel with the Fuel Cell System. A schematic of the installation is shown in Figure 4.

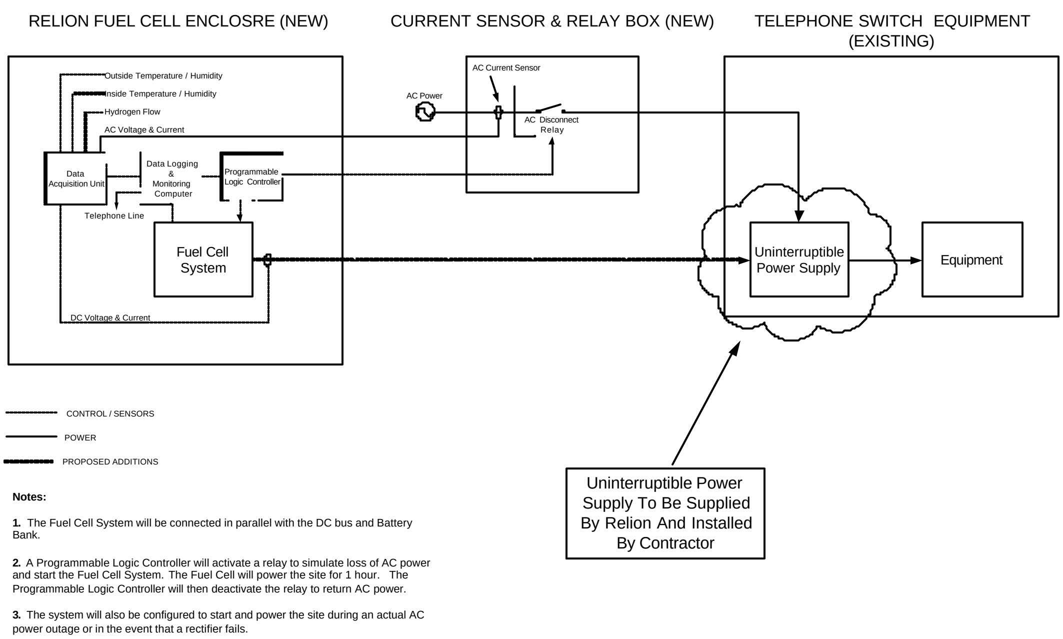

Figure 4. Fuel Cell / Uninterruptible Power Supply System

The fuel cells supply extended run power to the UPS system which in turn provides AC power to support telecom equipment installed at the customer's site. The telecom devices are listed in Table 1.

Table 1. Gabreski ANGB Telecom Equipment

Device	Voltage Rating (VAC)	Current Rating (Amp)	Load Rating (VA)
AT&T Definity MCC G3/SI Server	120	40	4800
Secure Logic ETM 3200 Modem	120	2.8	336
Data Smart 656 Analog Network CSU	120	2	240
CSI PA Amplifier	120	5.7	670
Total Equipment Load Rating:			**6046 VA**

When commercial AC power is available, the telecom equipment is supplied by the UPS through a 208 VAC rectifier. During an AC outage extended run time for the UPS system and telecom equipment was and still is provided by the ReliOn fuel cell system which bypasses the rectifier. The ReliOn fuel cell supplies power at 48 VDC and is connected to the 48 V battery string on the UPS system.

The 4-kW fuel cell power system was installed at Gabreski ANGB in July 2004. The complete fuel cell enclosure system as installed is shown in Figure 5. The new UPS installation was completed on September 22. Base personnel requested a period of preliminary testing before the telecom equipment was connected to the fuel cell. This initial testing was conducted between September 22 and December 9. During this time, the system accumulated 75 starts and 75 run hours. The equipment reliability and availability during this period were both 100%. The 1-year test program was started on December 10, 2004.

Figure 5. ReliOn Outdoor Enclosure System
At 106th Rescue Wing Headquarters, Building 250

The daily test runs were scheduled to occur during normal business hours over periods of representative equipment loads. This also allowed ease of scheduling if host site personnel, ReliOn staff, and guests wished to observe the tests. The data from the laptop computer in the outdoor enclosure was downloaded to a server at ReliOn by remote dial-up after each system test run. The data logging computer also included an alarm notification utility that automatically dialed preprogrammed phone numbers to notify ReliOn personnel of any alarm condition. One analogue POTS telephone line was used for remote monitoring at the site. The tests at Gabreski ANGB were timed as shown in Table 2.

Table 2. Gabreski ANGB CERL Test Schedule

Site No.	Site Name	Local Test Time (Eastern)
3-9	Gabreski Telecom Equipment	9:00 AM

The test run simulated a power outage everyday for a 60-minute time period in order to test the availability of the fuel cell system. A programmable logic controller (PLC) was installed with the system to simulate the grid outage by opening a relay to cut AC power to the UPS equipment. The PLC also monitored the run status of the fuel cells and reconnected AC power to the UPS equipment in the event of any type of operational failure that could have jeopardized the protected equipment. The fuel cells were connected directly to the 48 Volt DC bus at UPS equipment rack. Once a day, AC power to the UPS equipment was disconnected. At the same time, the fuel cells started and provided power to the loads for 1 hour. At the end of each test period, AC power was restored and the fuel cells shut down.

In addition to the daily test, the fuel cell systems were configured to monitor the commercial AC power grid as well as the status of the UPS system batteries at the site. Upon loss or failure of either power source, the fuel cells started automatically to provide up to 48 kWh of continuous run power to critical equipment at each site.

9.0 Electrical System

At the Gabreski ANGB telecom site, the fuel cell system was installed in a grid-independent mode with the only interconnection being an AC sensing circuit in the fuel cell enclosure.

The fuel cell system was in a standby/ready mode to provide backup power for critical DC equipment in the event of a loss of primary AC power. The following connections were established at each site:

- Electrical Requirements:
  - One 20 Amp circuit at each site for AC sense and the enclosure heater. The heater was designed to keep the environment around the fuel cell above freezing to facilitate startup. Once the fuel cell is running, it utilizes its own heat for operation.
  - AC disconnect relay between AC power and rectifier
  - DC connection between fuel cell system and DC bus in customer's equipment cabinet
  - The PLC, data monitoring equipment, and data logging computer were powered from the 24 VDC terminals inside the enclosure. This ensured that data continued to be recorded during any extended AC outage.
- Telephone Lines
  - One phone line required per site for data monitoring
  - One computer with dial-up capability at each site
  - See Appendix 2 for site specific connections

10.0 Thermal Recovery System

Because ReliOn's PEM fuel cells operate at low temperatures, the system is not a cogeneration system. The system was installed in an outdoor enclosure designed to maintain the internal temperature within the operating range of the I-1000.

11.0 Data Acquisition System

The telecom equipment load at Gabreski ANGB averaged between 1200 and 1500 watts. A Programmable Logic Controller (PLC) was used to start the fuel cell once a day for a test period of one hour. The PLC also energized a relay at the same time to disconnect AC power from the rectifier in the UPS system.

A data acquisition system was included in the enclosure to monitor and record the following:

- Inside temperature
- Inside Humidity
- Outside Temperature
- Outside Humidity
- AC Voltage at the site
- AC current at the shelter rectifier
- DC Voltage at the shelter DC bus
- DC current from the fuel cell
- Hydrogen fuel flow

All vital information from the I-1000 fuel cell was also monitored and recorded. The data-logging computer was connected to the data acquisition module and fuel cell via Ethernet. The data-logging computer was configured to dial a designated ReliOn personnel cell phone during any of the following alarm conditions:

- Loss of AC Voltage
- Low DC Voltage (Less than 50 VDC)
- Hydrogen Sensor Alarm
- Fuel Cell Major Alarm
- Hydrogen Bank Empty
- Enclosure Fan Alarm

The system was also configured to start automatically during a loss of the AC grid and in the event the facility DC bus voltage falls below a pre-determined limit (low voltage startup). The low voltage startup protected the telecom equipment in case of a facility rectifier/charger failure or a fault in the battery string. The low voltage start threshold was set at 50 VDC for the installation at Gabreski ANGB.

Daily run data for each site was available to host and US Army Corps of Engineers personnel through a password protected website. Monthly run data summaries through the entire project demonstration period are included in Appendix 3.

12.0 Fuel Supply System

The fuel cell systems operated with industrial grade hydrogen gas. Compressed gas is the easiest and most commercially available source of industrial grade hydrogen. The outdoor enclosure included two locked hydrogen storage and delivery systems which ensured that the compressed hydrogen cylinders were protected and accessible only to authorized personnel. A sketch of the hydrogen compartments is shown in Figure 6.

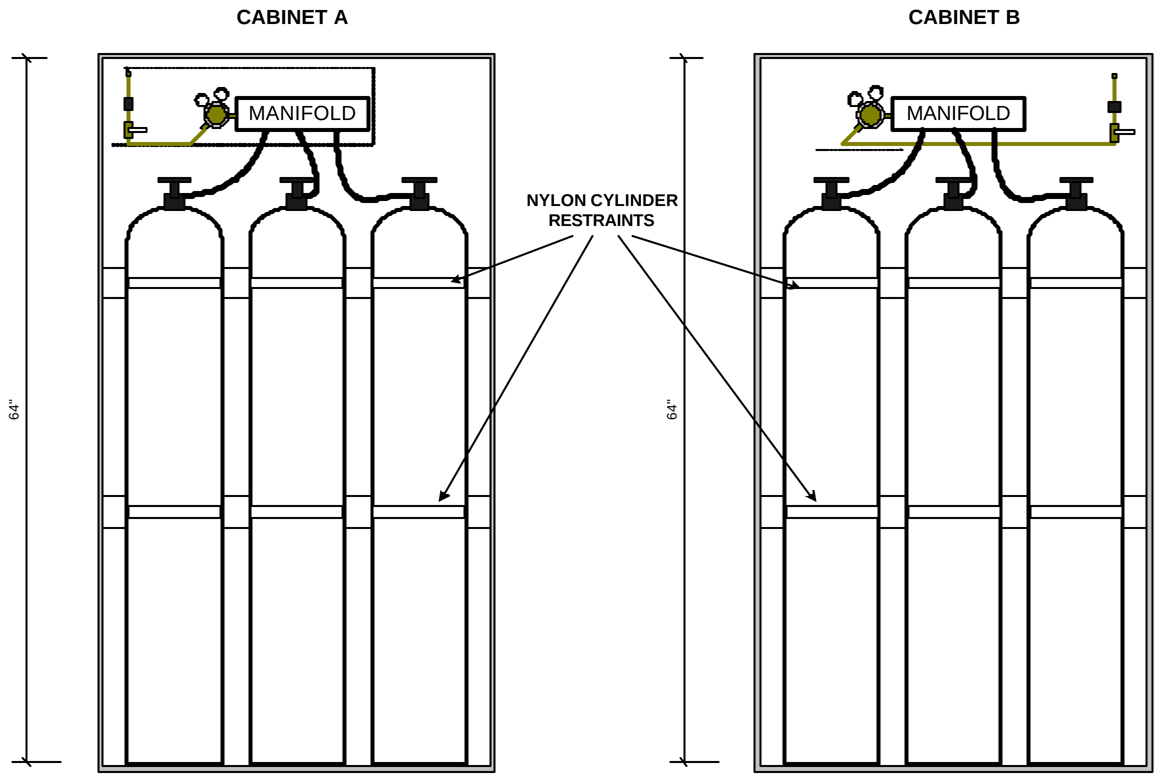

Figure 6. Hydrogen Fuel Compartments

The cylinders were typically size 300 (nominal 285 cu. ft or 8071 liter gas capacity at STP conditions), although size 200 could also be accommodated. Full cylinders were delivered with gas pressure at between 2000 and 2200 psig. Each of two hydrogen storage compartments contained three (3) cylinders directly connected into a high pressure manifold. The manifolds were each equipped with pressure switches and a regulator to reduce the gas pressure for delivery to the fuel cell. The pressure switches were monitored by the data logging computer which provided an alarm to the ReliOn personnel when the gas pressure fell to a pre-determined level. Hydrogen gas deliveries were made to each site by the local distributor for Airgas, Inc. at approximately 3 week intervals. Additional deliveries were scheduled as required to accommodate unplanned AC grid outages and extended test periods.

The optimal setting for the pressure regulators to the fuel cell was 40-50 psig. By adjusting the regulated pressures so that one bay is 5-10 psig higher than the other side, hydrogen was withdrawn from the higher pressure side until those cylinders were exhausted. The system then drew hydrogen from the other side allowing time to order and replace the depleted cylinders.

The fuel supply system and refill logistics generally performed well in the project. However there were two fuel outages due to missed deliveries over the test period. One occurred over the Christmas & New Years holiday (between December 29, 2004 and

January 5, 2005), and a second on February 23, 2005. These resulted in an overall loss of 9 starts and 9 hours of run time in December, January, and February. In addition, the PLC was manually stopped prior to the scheduled run on November 29, 2005 to allow a special fuel delivery following the Thanksgiving holiday. When fuel supply interruptions are removed from the calculations, reliability and availability of the commercial fuel cell equipment were both at 100% over the entire 1-year demonstration period.

13.0 Installation Costs

Table 3 shows a breakdown of project costs for the ReliOn PEM fuel cell backup power demonstration project at Gabreski ANGB. The total project proposed cost including ReliOn's profit and cost share for the entire contract was $363,781.64. Of this amount, $100,284 was allocated for the Gabreski ANGB site.

Table 3. Project Costs for Contract Number W9132T-04-C-0017 (Gabreski Site)

Task 1: Fuel Cell Power Plant		Plan			Actual Through End of Project
Direct Labor					
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	Training			$300	$300
Equipment					
I-1000 Fuel Cell		4	$8,050	$32,200	$32,200
Enclosure w/2 Fuel Wings		1	$5,950	$5,950	$5,950
Extended Rack for Hydrogen Delivery System		1	$2,500	$2,500	$2,500
Telecom UPS System		1	$3,800	$3,800	$3,800
Task 1 Subtotal				**$44,750**	**$44,750**

Task 2: Installation	Plan			Actual Through End of Project
General/Electrical Contractor				
General Contractor			$1,600	$1,600
Electrical Contractor			$4,800	$4,800
Materials & Expenses				
Crane/Fork Lift			$1,000	$1,000
Telecommunications			$2,600	$2,600
Task 2 Subtotal			**$10,000**	**$10,000**

Task 3: Performance Monitoring		Plan			Actual Through End of Project
Direct Labor					
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	Monitoring & Data Management			$2,600	$1,250
Principal Investigator	Monitoring & Data Management			$1,200	$2,550
Task 3 Subtotal				**$3,800**	**$3,800**

Task 4: Maintenance		Plan			Actual Through End of Project
Direct Labor					
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	On Site Training			$300	$300
Applications Engineer	Remote & Site Maintenance			$800	$400
Principal Investigator	Remote & Site Maintenance			$0	$400
Task 4 Subtotal				**$1,100**	**$1,100**

Table 3 (Continued).
Project Costs for Contract Number W9132T-04-C-0017 (Gabreski Site)

Task 5: Project Management & Reporting **Direct Labor**		Plan			Actual Through End of Project
Staff	Activity	Units	Unit Cost	Total Cost	
Project Manager	Management, Reporting, Meetings			$1,200	$1,400
Principal Investigator	Management, Reporting, Meetings			$800	$500
	Initial Project Description			$600	$600
	Monthly Status Report			$300	$650
	Midpoint Report			$600	$600
	Final Report			$600	$2,275
Task 5 Subtotal				**$4,100**	**$6,025**

Task 6: Travel	Plan			Actual Through End of Project
Managerial Travel			$1,685	$1,685
Technical Travel-Installation			$2,312	$2,312
Technical Travel-Maintenance			$9,556	$9,500
Technical Travel-Decommissioning			$1,894	$1,894
Task 6 Subtotal			**$15,447**	**$15,391**

Task 7: Decommissioning/Site Restoration **Direct Labor**		Plan			Actual Through End of Project
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	Site Work			$0	$1,200
Principal Investigator	Site Work			$0	$0
General/Electrical Contractor					
Labor				$3,200	$0
Materials & Expenses					
				$2,000	$4,451
Task 7 Subtotal				**$5,200**	**$5,651**

Task 8: Other Costs **Equipment & Expenses**	Plan			Actual Through End of Project
Hydrogen Fuel			$9,400	$9,400
Electrical Equipment			$7,500	$7,500
Task 8 Subtotal			**$16,900**	**$16,900**

Gabreski Total	**$101,297**	**$103,617**
Profit (10%)	$10,130	$10,362
Gabreski Total Project Cost	**$111,427**	**$113,979**
ReliOn Cost Share (10%)	($11,143)	($13,695)
Gabreski Total Project Billing	**$100,284**	**$100,284**

14.0 Milestones/Improvements

Through the end of the 1-year test program, there were 369 starts and 372.1 hours of run time. In addition to the daily test runs, the ReliOn Fuel Cell systems at these sites maintained critical equipment functionality over 4 primary power outages totaling 4 hours during the demonstration period.

15.0 Decommissioning/Removal/Site Restoration

Upon completion of the successful test program, the Gabreski ANGB personnel requested that the test site be converted to a commercially operating backup power system. This work was completed at the site by ReliOn Application Engineers during the week of May 15, 2006.

The conversion effort primarily involved removal of all test program equipment, upgrading the fuel cells to the latest version and a complete replacement of the system's cartridges to a later revision. All the test equipment was returned to ReliOn. The fuel cell upgrade effort also included minor electrical modifications to the I-1000 fuel cells and the latest firmware code. Finally, an updated set of drawings to include the changes made in the conversion and a system description document were created and provided to site personnel.

Figure 7. Fuel Cell System Following Conversion to Commercial Configuration

After the conversion was completed, the entire system was verified and commissioned as a new commercial installation. Training on the fuel cell system was offered and attended by a number of personnel.

16.0 Additional Research/Analysis

A further review of measured fuel consumption and calculated net system fuel conversion efficiency was performed to determine the cause of relatively low efficiencies reported over certain periods during the test program. This review of data revealed that the mass flowmeter installed to measure and record hydrogen fuel flow was adversely affected by low ambient temperatures. The mass flowmeter uses resistance temperature detectors (RTD) to measure a temperature differential within the metering section. This temperature differential is directly calibrated to mass flow of the hydrogen. At low ambient temperatures (near 0^oC) the temperature differential can exceed a predetermined maximum which causes the flowmeter to falsely produce a full scale reading. All run data was reviewed for the 1-year program to remove the false full scale flowmeter readings. The resulting fuel usage data and system efficiency calculations are shown in the attached performance data summary sheets. With this correction, the average net electrical efficiency for the system has changed from about 19% to 24.3% at an average fuel cell module output of 278 W (each of four 1 kW modules). The field test data collected during this demonstration program are in general agreement with laboratory testing as shown in Figure 8.

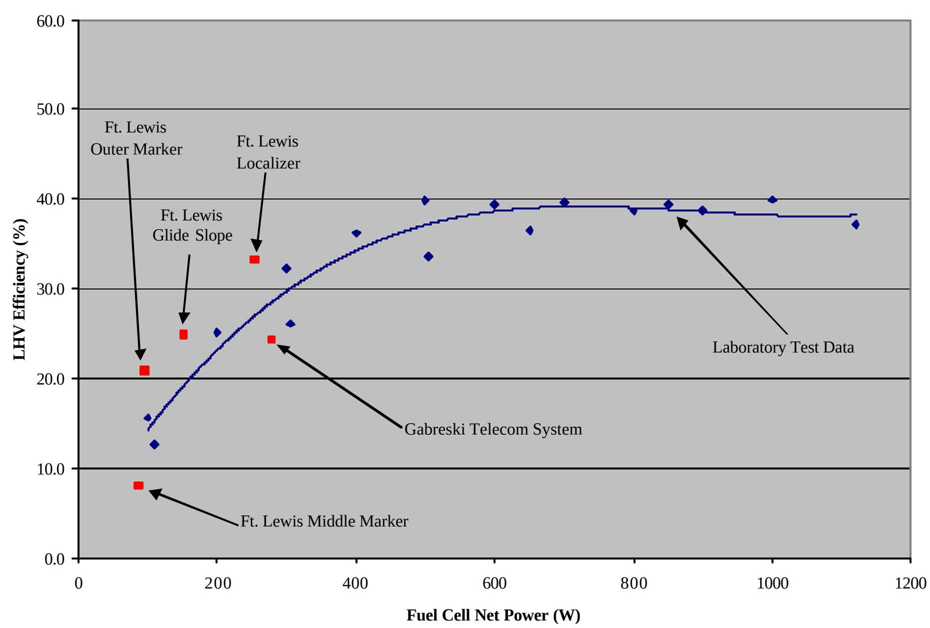

Figure 8. Fuel Cell Net Electrical Efficiency (LHV Basis)

17.0 Conclusions/Summary

Through the end of the 1-year test program, there were 369 starts and 372.1 hours of run time. In addition to the daily test runs, the ReliOn Fuel Cell systems at these sites maintained critical equipment functionality over 4 primary power outages totaling 4 hours during the demonstration period. According to CERL reporting requirements, overall reliability and availability calculations in this project have been based on total system performance, including special test equipment (computers, modems, PLC controllers) that is not part of ReliOn's commercial fuel cell product line. Availability calculations are also impacted by missed fuel deliveries if vendor scheduling or site access issues result in depletion of fuel reserves. Such incidents have been very infrequent over the 1-year demonstration period. When they have occurred, the fuel cells started on command but were unable to sustain energy delivery to the load, resulting in automatic reconnection of the site rectifier. On this basis, cumulative reliability for the demonstration program at Gabreski was 97.6% and cumulative availability was 97.3 percent. When fuel supply interruptions are removed from the calculations, reliability and availability of the commercial fuel cell equipment were both at 100% over the entire 1-year demonstration period.

At the conclusion of the demonstration test program, the fuel cell system was converted to commercial configuration by removal of special test control and monitoring equipment. Ownership and operation of the system has been turned over to the host and it remains on standby status to protect critical communication equipment at the site.

Appendix

1) ReliOn Fuel Cell System Site Preparation Contractor Scope of Work
2) Gabreski ANGB Fuel Cell Installation Drawings
3) Monthly Performance Data
4) Commissioning Procedures for the I-1000™ Fuel Cell & Outdoor Enclosure System

Appendix 1

ReliOn Fuel Cell System
Site Preparation
Contractor Scope of Work

ReliOn, Inc.
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Spokane, Washington 99216
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Facsimile 509-228-6510
www.relion-inc.com

June 25, 2004

Gabreski Air National Guard Base
Long Island, New York

Site Preparation and Enclosure Installation
Scope of Work

<u>All material required must be provided by the contractor unless stated</u>

<u>Site preparation must begin by July 7, 2004</u>

<u>All work must be completed by July 21, 2004</u>

Material Provided By ReliOn

1. ReliOn 4 kW Fuel Cell Enclosure System, including all internal components (see Detail 5 in Gabreski Installation Drawing Package).
2. Current Sensor and Relay Box, including AC current transducer and AC disconnect relay (see Detail 5 in the Gabreski Installation Drawing Package).

Material Provided By Contractor

1. All necessary permits for electrical work, excavation, and construction as required.
2. 8-inch concrete filled bollards (see Detail 2 in the Gabreski Installation Drawing Package).
3. Anchor bolts, washers, and nuts (see Detail 3 in the Gabreski Installation Drawing Package).
4. DC disconnect box and switch (see Detail 6 in the Gabreski Installation Drawing Package).
5. All wiring, conduit, clamps, supports, and other materials necessary to complete work as described in this Scope of Work.

Site Preparation

1. **Site:** The following work shall be completed at the 106th Rescue Wing Headquarters, Building 250 Gabreski Air National Guard Base, Long Island, New York. The ReliOn 4 kW Fuel Cell System will provide backup power to the telephone switch equipment located in the communications equipment room in Building 250. The Gabreski Installation Drawing Package details the installation at the site.

2. **Conduit Installation**: There is about a 40’ run for the AC circuit, DC circuit, and telephone wire between the ReliOn Fuel Cell Enclosure and the respective equipment within the communication room in Building 250. The Contractor shall independently verify the run distance and routing. The AC circuit, DC circuit, and telephone connections shall be made at the respective AC panel, DC battery bank, and telephone demarcation block within the communication room in Building 250. Use one (1) 2-inch EMT conduit for the DC circuit run (conduit number 1), one (1) 1-inch EMT conduit for the AC circuit run, (conduit number 2), and one (1) 1-inch EMT conduit for telephone and control/alarm wiring (conduit number 3). The conduits shall be properly supported and anchored above the drop ceiling space between the west exterior wall of Building 250. The conduit runs shall exit the west wall of Building 250 at an exterior wall elevation that is above the interior drop ceiling. At the exterior wall penetration, cut one (1) 2-inch diameter hole and two (2) 1-inch holes in the wall for the three conduits. Place conduit sleeves inside the three penetration holes. Install conduit pull elbows on each of the conduit sleeves on the outside of the penetration holes. Seal the penetrations with caulk. Use SCH 40 rigid metallic conduit for building exterior runs between the pull elbows and the ReliOn Fuel Cell Enclosure. The ReliOn Enclosure will be 2’-6” away from the west exterior wall of Building 250 (see Detail 2 in the Gabreski Installation Drawing Package). The conduits should span the 2’-6” distance at an elevation of at least 8’ above grade. If this is not feasible or practical, stop work and immediately contact ReliOn Project Manager, Gerry Snow at (509) 228-6682. The conduits shall run down the outside of the building to grade level. Install 90^{o} sweep bends to extend the conduits at grade level to the ReliOn Enclosure (see Detail 1 in the Gabreski Installation Drawing Package). The conduits will penetrate the ReliOn Enclosure at the kick panel below the left side equipment cabinet (viewed from the rear of the enclosure). At the kick panel, cut one (1) 2-inch diameter hole and two (2) 1-inch holes for the three conduits. Install conduit pull elbows and provide a water tight seal at each of the three enclosure penetrations.

3. **Inside Conduit Installation:** In the communication room in Building 250, install a DC disconnect box and switch near the telephone switch battery bank (Detail 6 in the Gabreski Installation Drawing Package). Extend the 2-inch EMT conduit run (conduit number 1) from the ReliOn Fuel Cell Enclosure to the battery disconnect box. Continue the 1-inch EMT conduit for the AC power circuit (conduit number 2) from the ReliOn Enclosure to the AC circuit breaker panel. Extend the one 1-inch EMT conduit for the control / alarm conduit penetration (conduit number 3) to the telephone demarcation block. Install an additional 1-inch EMT conduit from the telephone demarcation block to the telephone switch equipment cabinet. This conduit will carry the control wiring from the ReliOn Enclosure for the AC disconnect relay.

4. **Ground Stake Installation:** At the west exterior wall of Building 250, install a new code-conforming ground stake at the location shown on Detail 2 in the Gabreski Installation Drawing Package.

5. **Fuel Cell Pad Preparation:** At the west exterior wall of Building 250, install twelve (12) 3/8” anchor bolts in the asphalt according to the bolt pattern as illustrated in Detail 3 in the Gabreski Installation Drawing Package.

6. **Cable/Wire Installation:** Install the following wires and cables between the communication room equipment in Building 250 and the ReliOn Fuel Cell Enclosure.

    a. **DC Power Cables:** Install two (2) runs of 2/0 AWG Type THHN copper cable in conduit number 1 (2-inch conduit). Leave 10-feet of cable coiled at each end.

    b. **AC Power Wires**: Install three (3) 12 AWG Type THHN copper wires (Black, White & Green) in conduit number 2. Leave 10 feet of wire coiled at each end.

    c. **Control/Alarm Wires**: Install one (1) solid conductor (not stranded) CAT 3 telephone cable in conduit number 3 from the telephone demarcation block to the ReliOn Enclosure. Install five (5) black 18 AWG Type THHN copper wires and five (5) red 18 AWG Type THHN copper wires in conduit number 3 from the telephone demarcation block to the ReliOn Enclosure. Install five (5) black 18 AWG Type THHN copper wires and five (5) red 18 AWG Type THHN copper wires in conduit number 3 from the telephone demarcation block to the telephone switch equipment cabinet. Leave 10 feet of wire coiled at each end.

Enclosure Installation

1) **Enclosure Placement**: At the west exterior wall of Building 250, place the ReliOn Fuel Cell Enclosure according to Detail 2 in the Gabreski Installation Drawing Package. It is critical that the ReliOn Enclosure is facing the correct direction. If there are any questions, stop work and immediately contact ReliOn Project Manager, Gerry Snow at (509) 228-6682. Bolt the enclosure to the asphalt using the 12 embedded anchor bolts previously installed. Use 3/8" washers and nuts.

2) **Electrical Connections (See details in the Gabreski Installation Drawing Package)**:

    a) **AC Power Wires**: Connect the AC power wires to the spare 15 to 20 Amp circuit breaker in the communication room circuit breaker box. Connect the AC power wires to the two 20 Amp circuit breakers in the fuel cell enclosure.

    b) **AC Disconnect Relay:** Disconnect the AC power wire from the telephone equipment rectifier (UPS system) and place the AC disconnect relay and current sensor in line as shown in Detail 5 in the Gabreski Installation Drawing Package. A ReliOn applications engineer will connect the control wires to the AC disconnect relay and current sensor.

    c) **Control / Alarm Wires:** A ReliOn applications engineer will connect all control wires inside the communication room and inside the ReliOn Fuel Cell Enclosure.

d) **DC Power Wires:** Connect the DC power wires at the ReliOn Enclosure terminal block first. Connect the DC power wires to the telephone equipment battery bank via the DC disconnect box after the wires have been connected at the fuel cell enclosure.

e) **Ground Cable:** Install a 1/0 AWG bare copper ground cable from the ground stake to the ReliOn Enclosure internal ground lug as shown in Detail 4 in the Gabreski Installation Drawing Package. Use a clamp or other approved connection compatible with local code and practice for equipment grounding.

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July 7, 2004

Gabreski Air National Guard Base
Long Island, New York

Addendum 1 to June 25, 2004 Scope of Work

Anchoring of ReliOn Fuel Cell Enclosure
Increase DC Power Cable Size

Enclosure Installation

7. **Fuel Cell Pad Preparation:** At the west exterior wall of Building 250, core drill the asphalt to a diameter of approximately 8" and a minimum depth of 2'-6", or as required by local building code to meet frost depth requirements at twelve (12) locations corresponding to the anchor bolt pattern as illustrated in Detail 3 in the Gabreski Installation Drawing Package. Pour concrete in the prepared holes to bring the finished surface even with the surrounding asphalt. After the concrete as properly cured install twelve (12) 3/8" anchor bolts according to the bolt pattern as illustrated in Detail 3 in the Gabreski Installation Drawing Package.

8. **Enclosure Placement**: At the west exterior wall of Building 250, place the ReliOn Fuel Cell Enclosure according to Detail 2 in the Gabreski Installation Drawing Package. It is critical that the ReliOn Enclosure is facing the correct direction. If there are any questions, stop work and immediately contact ReliOn Project Manager, Gerry Snow at (509) 228-6682. Bolt the enclosure to the asphalt using the 12 embedded anchor bolts previously installed. Use 3/8" washers and nuts.

DC Power Cable

1. **DC Power Cables:** Based on a run length of 110' between the UPS in the communication room and the ReliOn Fuel Cell Enclosure, the DC power cable will need to be increased from the previously specified 2/0 AWG to 350 MCM. Run 350 MCM Type THHN copper braided cable between the DC disconnect box and the ReliOn Fuel Cell Enclosure. Run 2/0 AWG Type THHN stranded copper cable between the DC disconnect box and the UPS.

2. **DC Power Connections:** Use Thomas & Betts (or equivalent) H Taps and covers to reduce the cable size at each end of the 350 MCM cable to 2/0. This will allow connection to terminals at the DC disconnect box and the ReliOn Fuel Cell Enclosure.

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September 10, 2004

Gabreski Air National Guard Base
Westhampton Beach, Long Island, New York

Telecom Uninterruptible Power Supply System

Equipment Installation Scope of Work

<u>All material required must be provided by the contractor unless stated</u>

<u>Equipment installation must begin by Monday, September 20, 2004</u>

<u>All work must be completed by Tuesday, September 21, 2004</u>

Material Provided By ReliOn

1. Purcell Systems 48 VDC Telecom Uninterruptible Power Supply (UPS) Rack.
2. Valere Power Rectifier Installation, Operation, & Maintenance Manual (attached separately)
3. Exceltech Inverter Installation & Operation Manual (attached separately)
4. 20 Amp Plug-In Outlet Strip with 6 120 VAC receptacles (NEMA 5-15). Wiremold ULB620-6 (Grainger Stock No. 1A948), or equivalent
5. A ReliOn Application Engineer will be present during equipment installation to provide guidance and assistance in equipment power supply cut-over.

Material Provided By Contractor

1. All necessary permits for electrical work as required.
2. Anchor bolts, washers, and nuts to secure UPS rack to the floor in the communications equipment room in Building 250 (see Purcell Systems power rack drawing 006-000065-01).
3. 100 Amp DC junction box
4. All wiring, terminals, conduit, clamps, supports, and other materials necessary to complete work as described in this Scope of Work.

Application

ReliOn is currently commissioning a 4 kW Fuel Cell System to provide backup power for a PBX telecom system located at an Air National Guard Base in New York State. As part of this project, ReliOn is required to install a new telecom UPS system that will function in parallel with the Fuel Cell System. A schematic of the installation is shown in Figure 1.

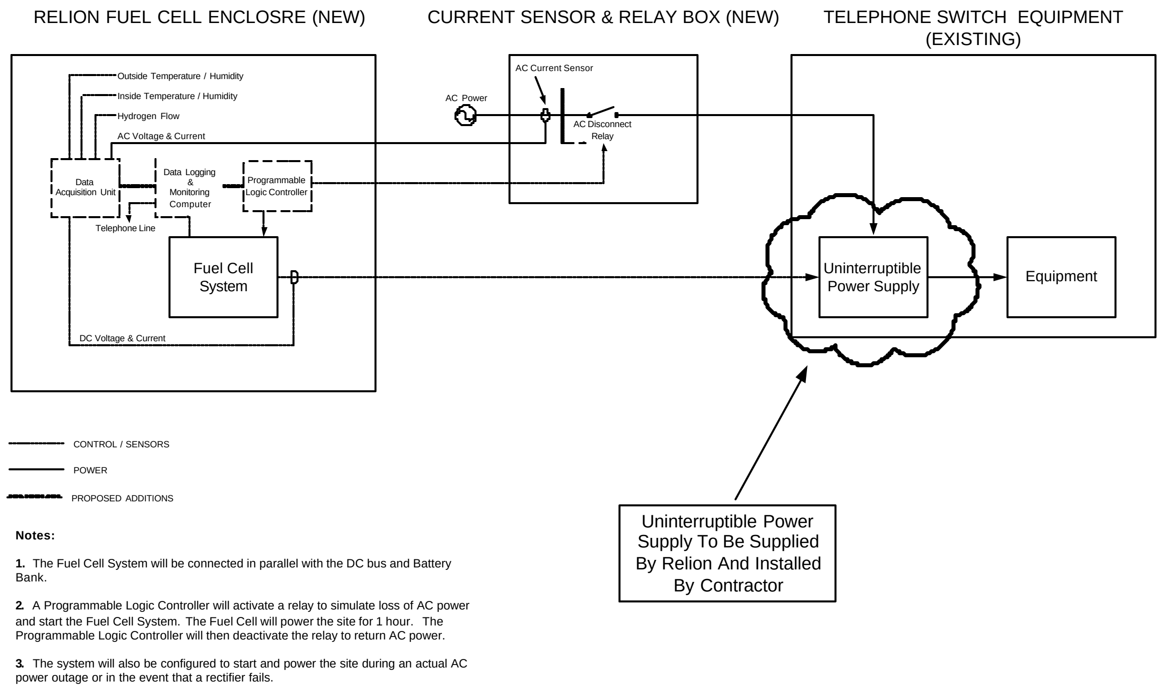


Figure 1. Fuel Cell / Uninterruptible Power Supply System

The new UPS system will provide AC power to support four (4) telecom devices currently installed at the customer's site. These devices are summarized in Table 1.

Table 1. Gabreski ANGB Telecom Equipment

Device	Voltage Rating (VAC)	Current Rating (Amp)	Load Rating (VA)	Plug Type (NEMA)
AT&T Definity MCC G3/SI Server	120	40	4800	5-50P
Secure Logic ETM 3200 Modem	120	2.8	336	1-15P
Data Smart 656 Analog Network CSU	120	2	240	1-15P
CSI PA Amplifier	120	5.7	670	1-15P

Total Equipment Load Rating: 6046 VA

The telecom UPS system will be connected to building AC through a new 208 VAC, 60 Amp circuit. Extended run time for the UPS system and telecom equipment will be provided by the ReliOn fuel cell system. The ReliOn fuel cell supplies power at 48 VDC and will be connected to the 48 V battery string on the telecom UPS system.

Telecom UPS Installation

3. **Site:** The following work shall be completed at the 106th Rescue Wing Headquarters, Building 250 Gabreski Air National Guard Base, Long Island, New York. The supplied Purcell Systems Telecom UPS rack is to be located adjacent to the existing PBX telecom system (shown in Figure 2) located in the communications equipment room in Building 250.

Figure 2. AT&T Definity PBX System

4. **Telecom UPS Rack Placement:** The exact location of the telecom UPS rack shall be as directed by the base POC Chief Master Sergeant Stephen Thorenz, and/or ReliOn Project Manager Gerry Snow. Both individuals will be present during equipment installation. Install four (4) anchor bolts in the concrete floor according to the bolt pattern as illustrated in Purcell Systems power rack drawing 006-000065-01.

5. **Battery Installation:** A ReliOn Application Engineer will assist with unpacking and installation of four (4) each, 12 V, 90 Amp-hr batteries in the battery tray. Batteries are connected in series to form a 48 VDC battery string. Battery string is connected to the rectifier on the telecom UPS rack using Anderson style DC connectors (provided).

6. **Telecom UPS Grounding:** Install a 1/0 AWG bare copper ground cable from the power supply rack chassis to building ground. Do not connect the ground cable to the copper DC bus bar as the DC system must float. Use clamps or other approved connections compatible with local code and practice for equipment grounding.

AC Supply To Power Supply Rack

Pull a new 208 VAC, Single Phase, 60 Amp circuit to supply the rectifier. Mount a readily accessible disconnect device to the adjacent room wall. Connect AC supply to the rectifier input terminals using code approved wiring and conduit. See Figure A-4 for connection points. See Valere Power Compact DC Power System manual (Adobe file "I Shelf Installation Manual.pdf").

DC Supply From ReliOn Fuel Cell

1. **DC Junction Box**: Provide and install DC junction box to left rack post (as viewed from front of UPS rack). See Figure A-6.

2. **Connection from DC Disconnect Box:** Run 2/0 AWG Type THHN stranded copper cable between the existing DC disconnect box and the DC junction box. See Figure A-6. Use code approved connectors and conduit.

3. **Connection to Rectifier DC Terminals:** Run 2 AWG Type THHN stranded copper cable between the DC junction box and the rectifier DC terminals. Use two-stud ¼" lugs (5/8" stud center-to-center spacing). See Figure A-5.

AC Supply To Telecom Equipment

120 VAC power will be supplied to the telecom equipment listed in Table 1 via the AC distribution panel located at the top of the telecom UPS rack. See Figure A-7.

1. **AT&T Definity PBX Switch**: Remove the dead front panel on the AC distribution panel. Hard wire the 120 VAC, 40 Amp AT&T Definity PBX Switch directly to the 40 Amp breaker on the AC distribution panel. Use code approved wiring, connectors, and conduit as required.

2. **20 Amp Outlet Strip:** Mount 120 VAC, 20 Amp plug-in outlet strip (supplied by ReliOn) to left rack post (as viewed from front of UPS rack). Hard wire the outlet strip directly to the 20 Amp breaker on the AC distribution panel. Use code approved wiring, connectors, and conduit as required. The following telecom equipment will be connected to the outlet strip using existing 1-15P cords and plugs.

    - Secure Logic ETM 3200 Modem, 120 VAC, 2.8 Amp

- Data Smart 656 Analog Network CSU, 120 VAC, 2 Amp
- CSI PA Amplifier, 120 VAC, 5.7 Amp

3. **Spare Breakers:** The remaining 15 Amp breaker (one each) and 10 Amp breakers (three each) on the AC distribution panel are spares for future use.

4. Re-install the dead front panel on the AC distribution panel.

Appendix 2

Gabreski Fuel Cell Installation Drawings

REV	DESCRIPTION	DATE	ENG	DFT
A	First Issue	06-23-2004	GCS	GCS
B	Revised Ground Connection	06-29-2004	GCS	GCS
C	Added Control Din Rail (Pg 9)	07-13-2004	GCS	DWL

Index of Details

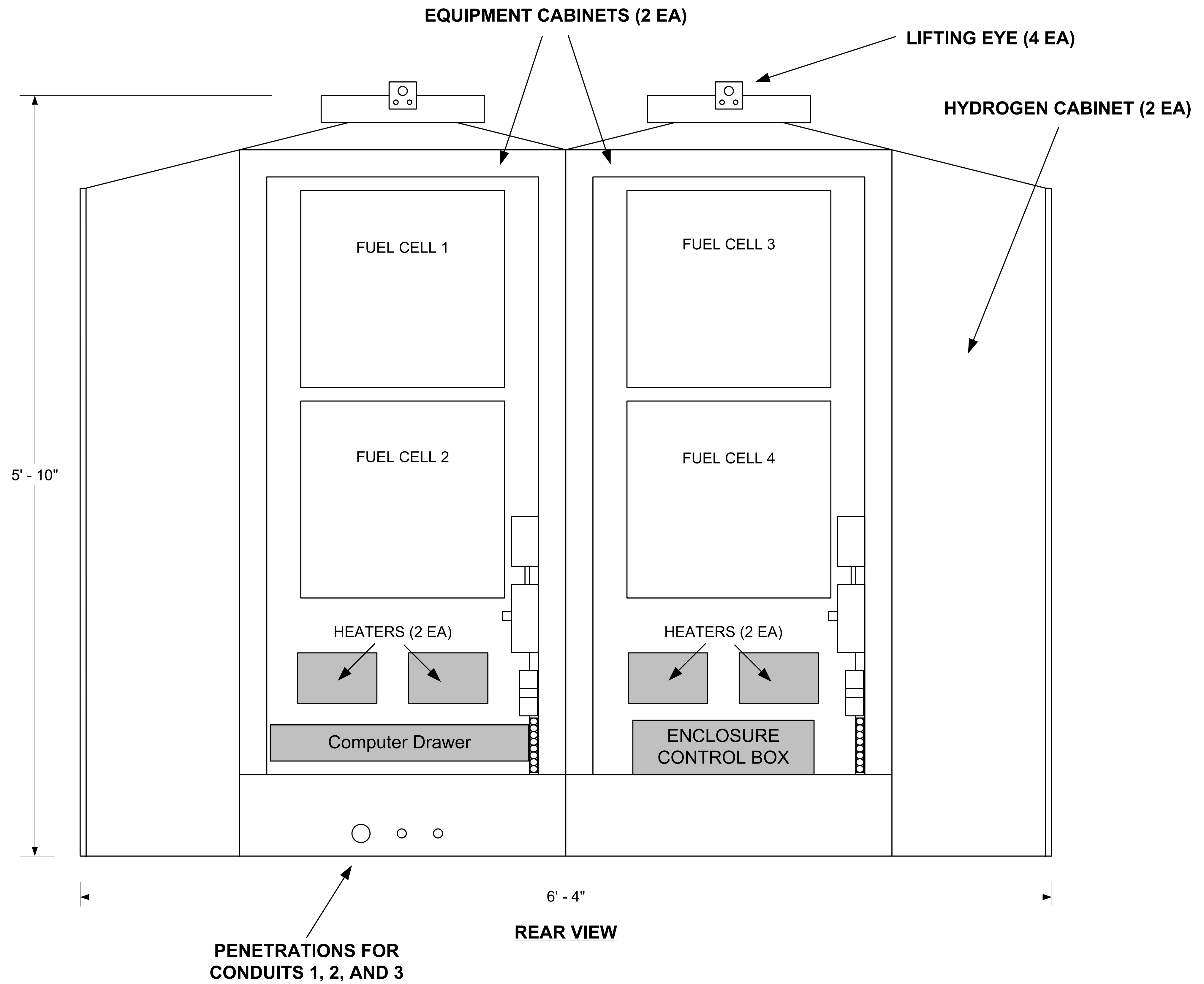
ReliOn

15913 East Euclid Avenue
Spokane, Washington 99216

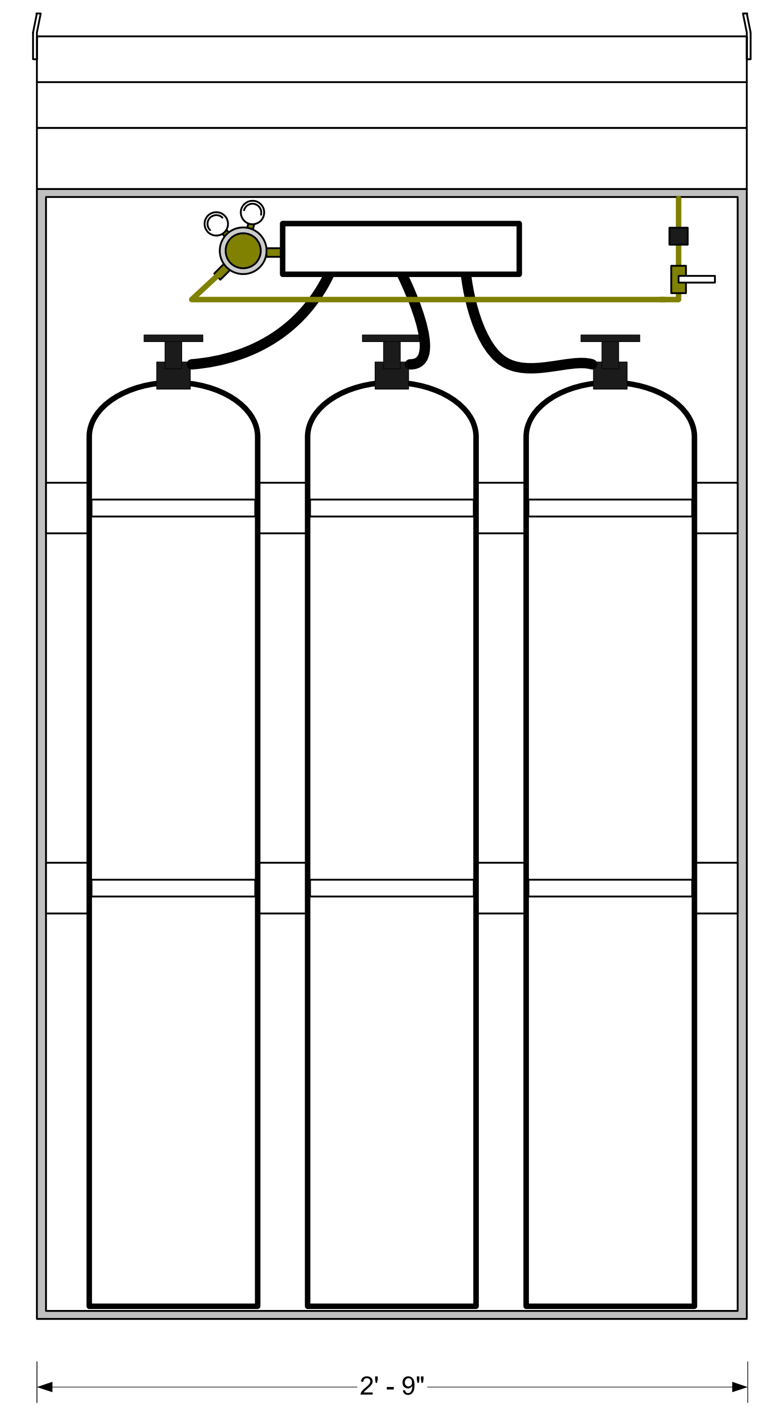
PROJECT	CERL III	TITLE	Installation Drawings
CUSTOMER	Army Corp of Engineers	FILE	Gabreski Install Rev C.vsd
SITE	Gabreski ANGB, NY	SHEET	1 of 9

REV	DESCRIPTION	DATE	ENG	DFT
A	First Issue	06-23-2004	GCS	GCS
B	Revised Ground Connection	06-29-2004	GCS	GCS
C	Added Control Din Rail (Pg 9)	07-13-2004	GCS	DWL

DET 1 ENCLOSURE VIEWS



REAR VIEW



SIDE VIEW

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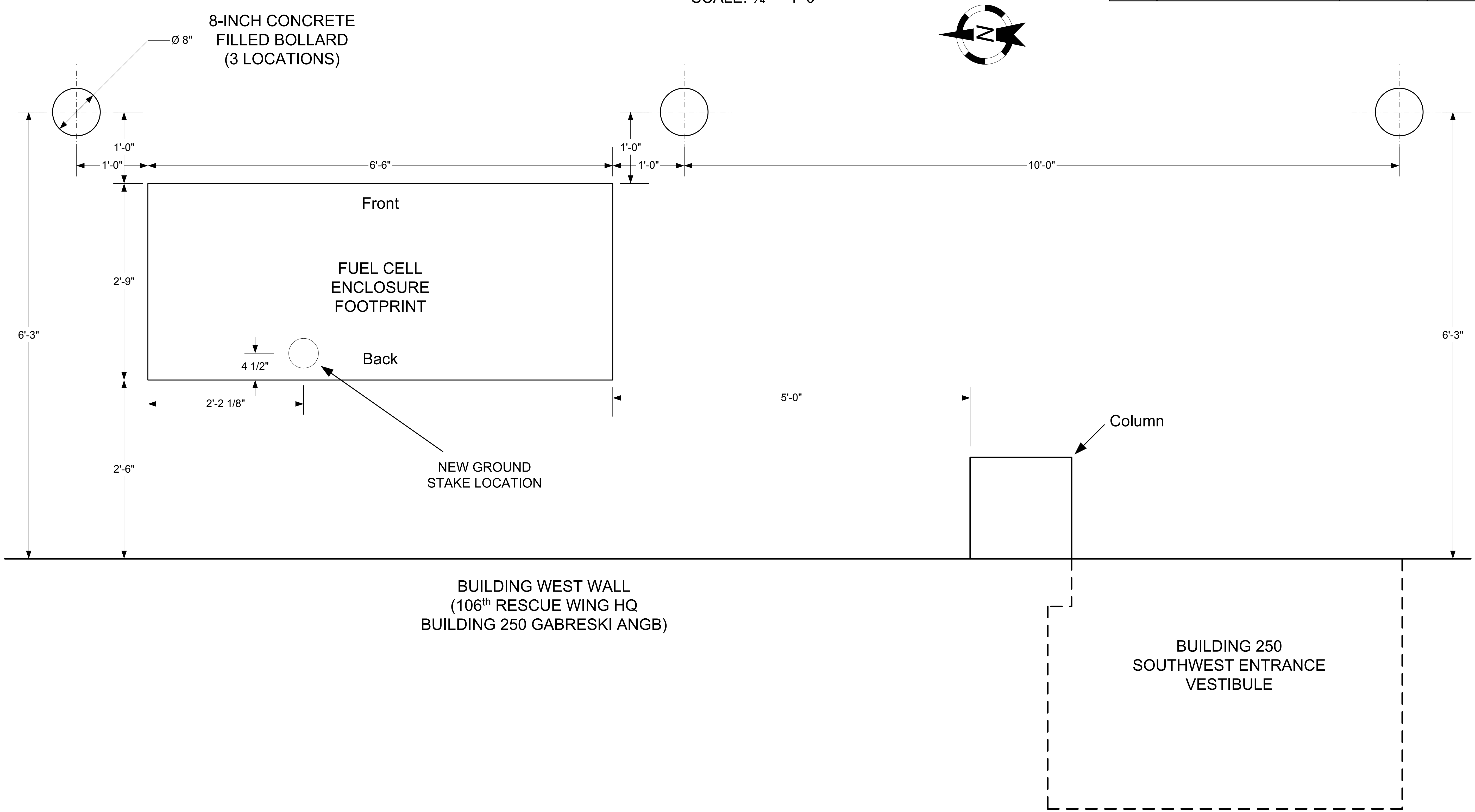
REV	DESCRIPTION	DATE	ENG	DFT
A	First Issue	06-23-2004	GCS	GCS
B	Revised Ground Connection	06-29-2004	GCS	GCS
C	Added Control Din Rail (Pg 9)	07-13-2004	GCS	DWL

DET 2 ENCLOSURE PLACEMENT

SCALE: ¾" = 1'-0"



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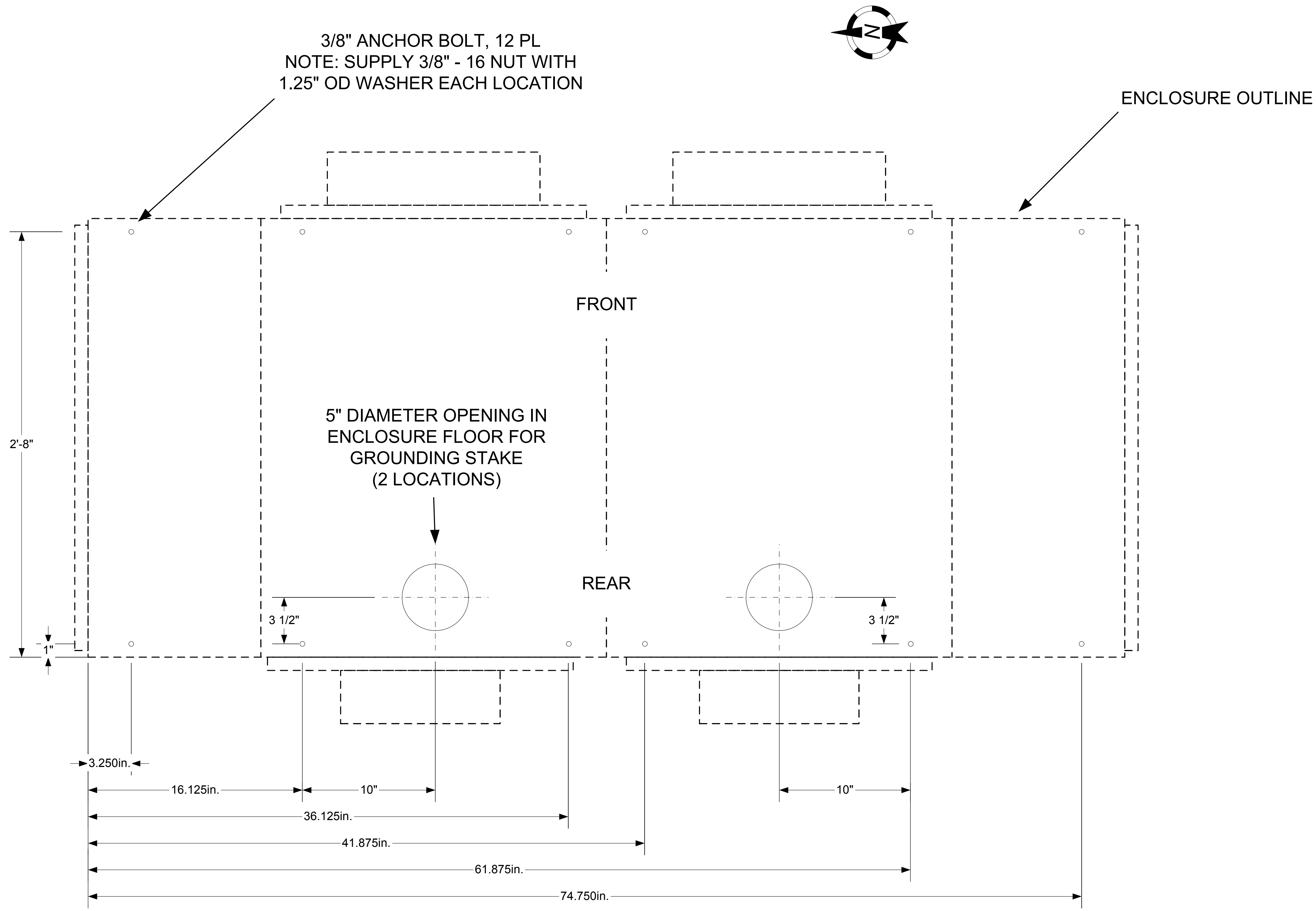
		SITE Gabreski ANGB, NY	SHEET 3 of 9

REV	DESCRIPTION	DATE	ENG	DFT
A	First Issue	06-23-2004	GCS	GCS
B	Revised Ground Connection	06-29-2004	GCS	GCS
C	Added Control Din Rail (Pg 9)	07-13-2004	GCS	DWL

DET 3 ENCLOSURE ANCHOR BOLT INSTALLATION

SCALE: 1 ½" = 1'-0"



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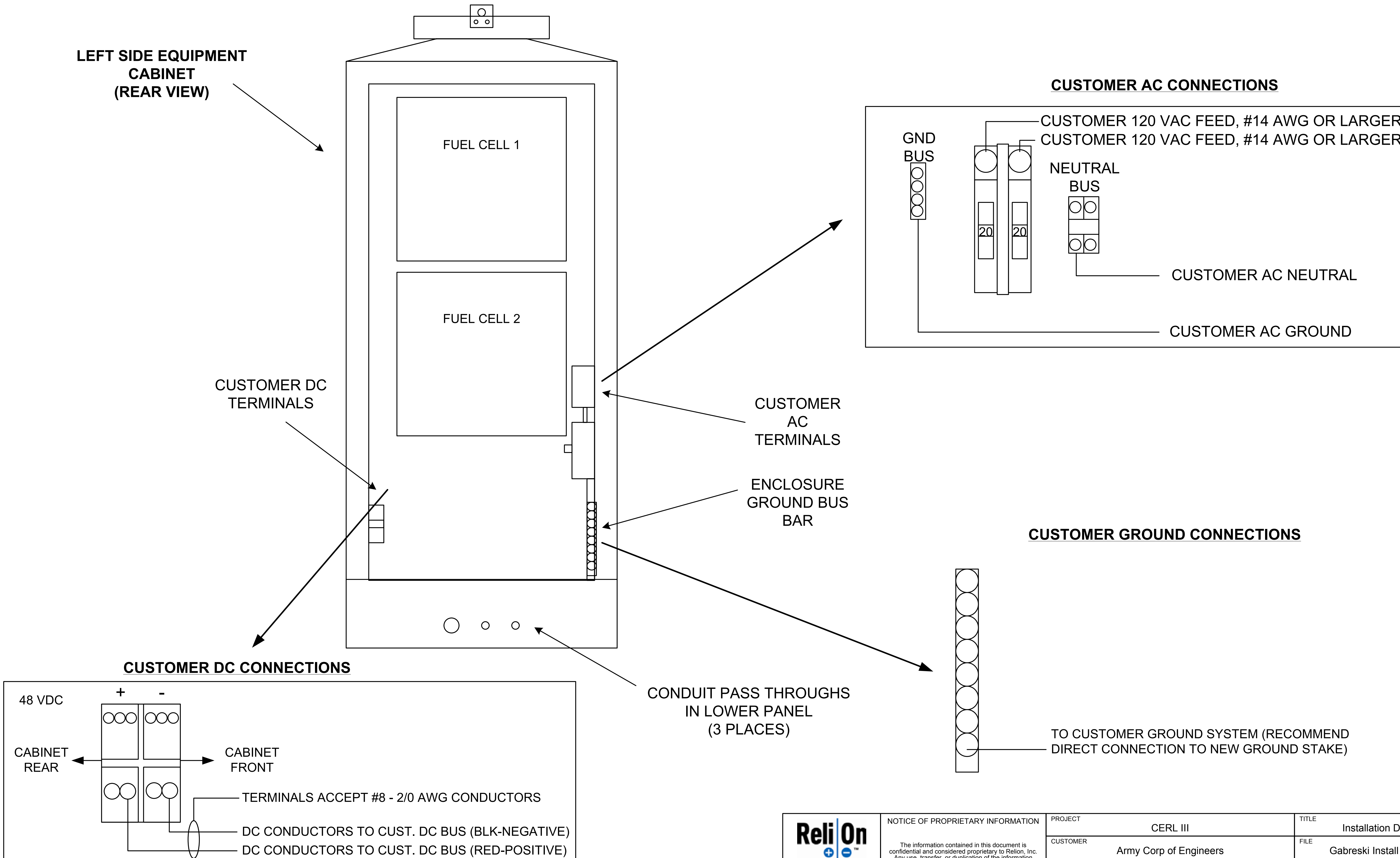
REV	DESCRIPTION	DATE	ENG	DFT
A	First Issue	06-23-2004	GCS	GCS
B	Revised Ground Connection	06-29-2004	GCS	GCS
C	Added Control Din Rail (Pg 9)	07-13-2004	GCS	DWL

DET 4 AC AND DC POWER CONNECTIONS AT FUEL CELL Enclosure

NO SCALE



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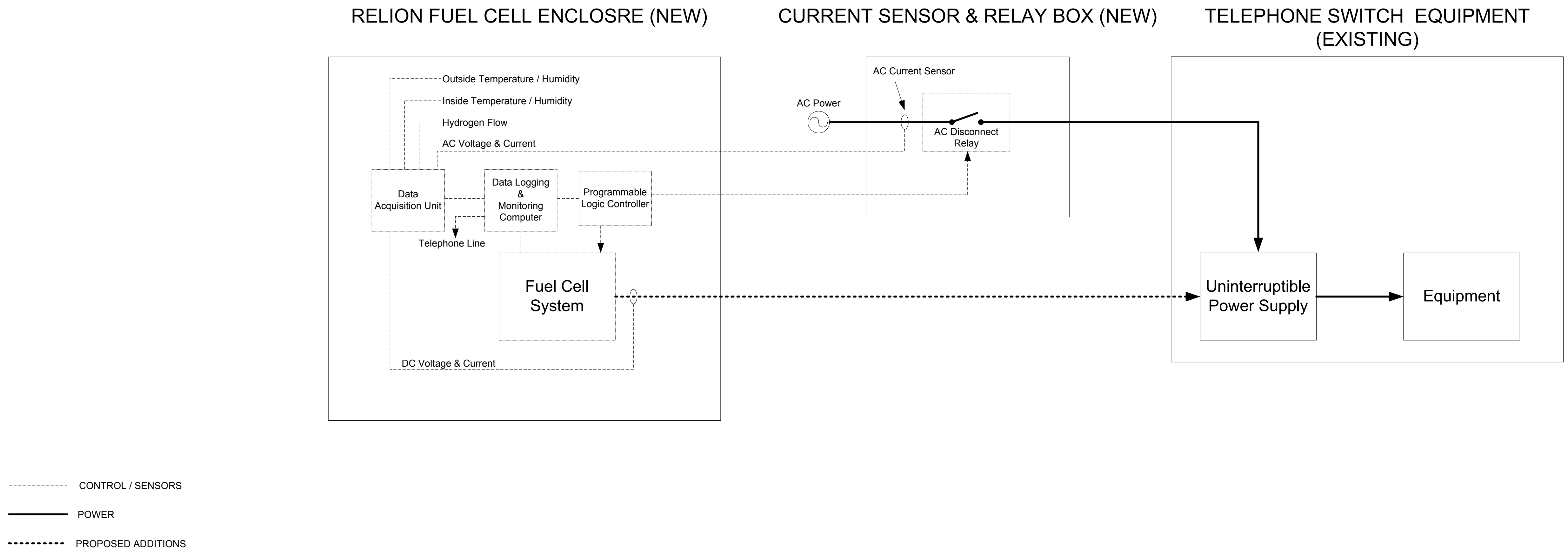
REV	DESCRIPTION	DATE	ENG	DFT
A	First Issue	06-23-2004	GCS	GCS
B	Revised Ground Connection	06-29-2004	GCS	GCS
C	Added Control Din Rail (Pg 9)	07-13-2004	GCS	DWL

DET 5 FUNCTIONAL BLOCK DIAGRAM

NO SCALE



Notes:

1. The Fuel Cell System will be connected in parallel with the DC bus and Battery Bank.

2. A Programmable Logic Controller will activate a relay to simulate loss of AC power and start the Fuel Cell System. The Fuel Cell will power the site for 1 hour. The Programmable Logic Controller will then deactivate the relay to return AC power.

3. The system will also be configured to start and power the site during an actual AC power outage or in the event that a rectifier fails.

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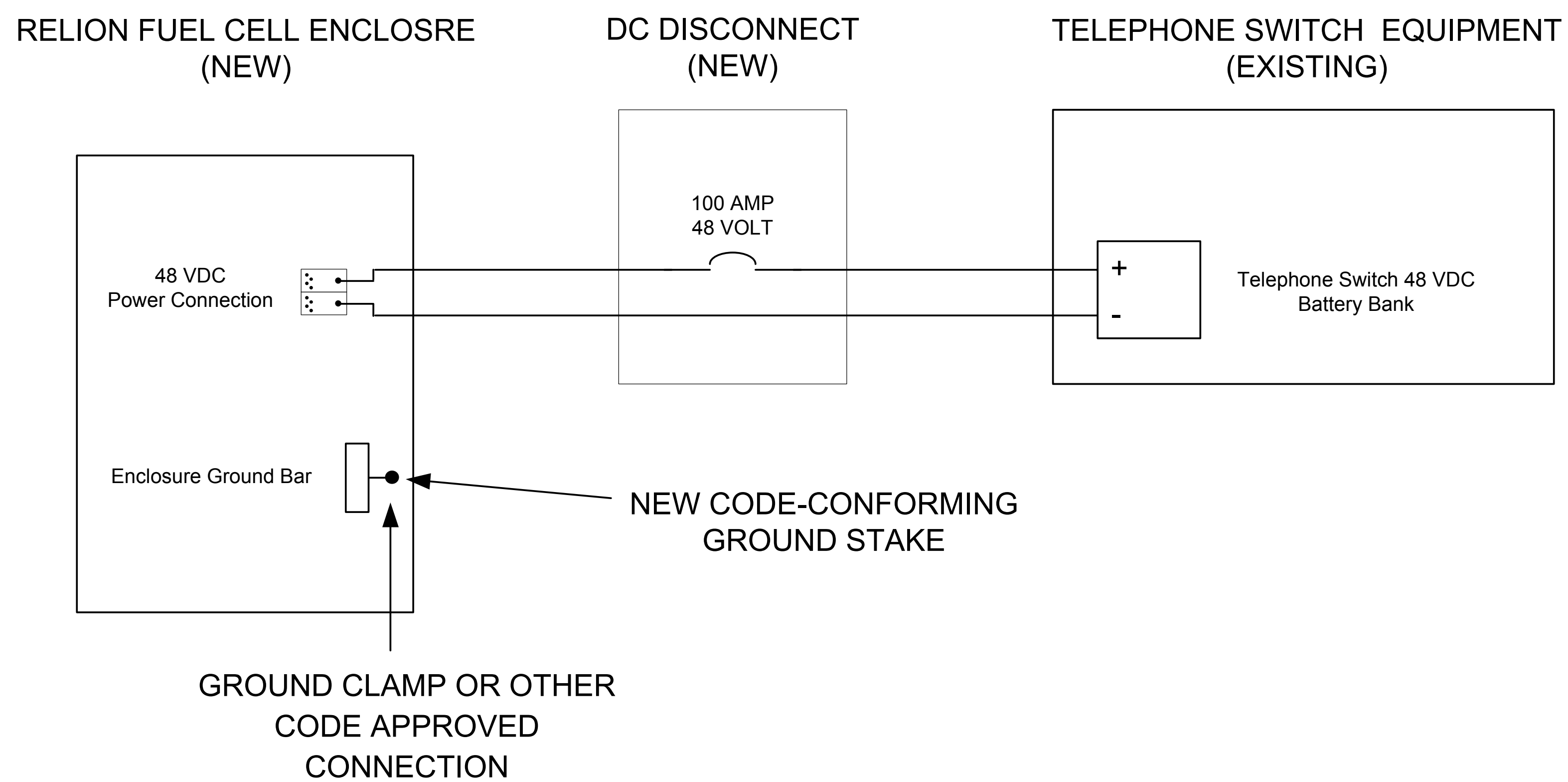
CUSTOMER	Army Corp of Engineers	FILE	Gabreski Install Rev C.vsd
SITE	Gabreski ANGB, NY	SHEET	6 of 9

REV	DESCRIPTION	DATE	ENG	DFT
A	First Issue	06-23-2004	GCS	GCS
B	Revised Ground Connection	06-29-2004	GCS	GCS
C	Added Control Din Rail (Pg 9)	07-13-2004	GCS	DWL

DET 6 DC POWER CONNECTIONS

NO SCALE



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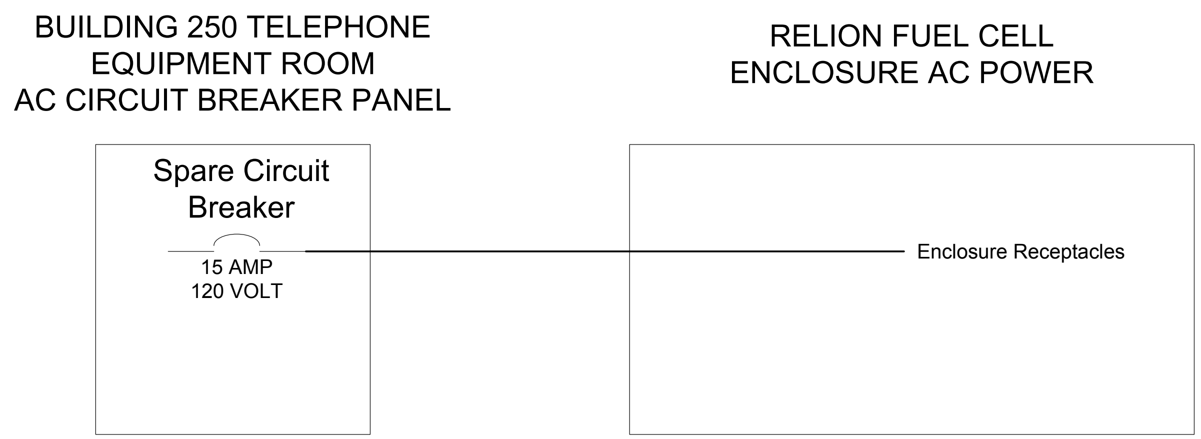
REV	DESCRIPTION	DATE	ENG	DFT
A	First Issue	06-23-2004	GCS	GCS
B	Revised Ground Connection	06-29-2004	GCS	GCS
C	Added Control Din Rail (Pg 9)	07-13-2004	GCS	DWL

DET 7 AC POWER CONNECTIONS

NO SCALE



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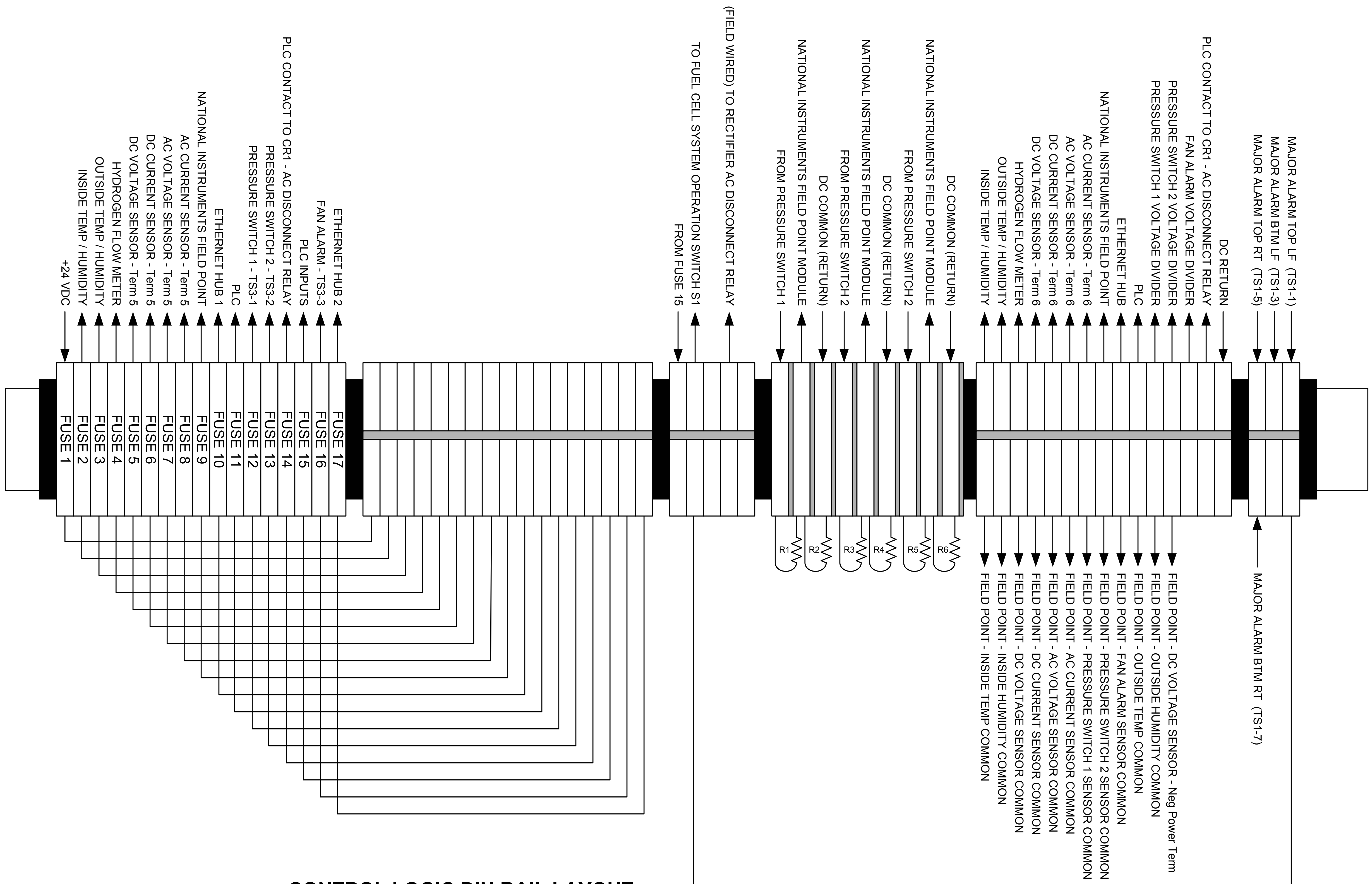
		SITE Gabreski ANGB, NY	SHEET 8 of 9

REV	DESCRIPTION	DATE	ENG	DFT
A	First Issue	06-23-2004	GCS	GCS
B	Revised Ground Connection	06-29-2004	GCS	GCS
C	Added Control Din Rail (Pg 9)	07-13-2004	GCS	DWL



CONTROL LOGIC DIN RAIL LAYOUT

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PROJECT	CERL III	TITLE	Installation Drawings
CUSTOMER	Army Corp of Engineers	FILE	Gabreski Install Rev C.vsd
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Appendix 3

Monthly Performance Data

ReliOn PEM Fuel Cell Performance Data

System Number:	**3-9**		**Commission Date:**	**22-Sep-04**			**Site Location(City,State):**	**Westhampton, New York**	
Site Name:	**Gabreski ANGB (NY) Telecom PBX Switch**		**Start of 1 Year Test Program:**	**10-Dec-04**					
Fuel Type:	**Hydrogen**		**Fuel Cell Type:**	**Modular PEM**					
Lower Heating Value:	**266.6**	**(Btu/scf)**	**Maintenance Contractor:**	**ReliOn, Inc.**					
Lower Heating Value:	**9.79**	**(kJ/liter)**	**Local Residential Fuel Cost per therm:**		**$/therm**	(Note 17)	**Local Base Fuel Cost per therm:**	**$/therm**	(Note 18)
Capacity kW	**4**		**Local Residential Electricity Cost per kWhr:**		**$/kWhr**	(Note 19)	**Local Base Electricity Cost per kWhr:**	**$/kWhr**	(Note 20)

Month	Total Time in Month	Total Run Time During Month	Total Run Time During Scheduled Test Periods (Note 1)			Attempted Starts	Actual Starts	Availability (Note 2)	Reliability (Note 3)	Net Energy Produced	Plant Capacity	Average Output (Note 4)	Capacity Factor (Note 5)	Fuel Usage		Electrical Efficiency (Note 6)	Thermal Heat Recovery	Heat Recovery Rate (Note 7)	Thermal Efficiency (Note 8)	Overall Efficiency (Note 9)	Number of Scheduled Outages	Scheduled Outage Hours	Number of Unscheduled Outages	Unscheduled Outage Hours	Notes
	(Hours)	(Hours)	(Hours) Scheduled	(Hours) Actual	(Hours) Cumulative			(%)	(%)	(kWe-hr)	(kW)	(kWe)	(%)	(liters)	(kJ, LHV)	(%, LHV)	(kJ)	(kWth)	(%, LHV)	(%, LHV)		(Hours)		(Hours)	
Dec 2004	528	19.3	22.0	19.0	19.0	23	20	86%	87%	21.67	4	1.141	1.03%	33955.7	332426.6	23.47%	0.0	0.00	0.00%	23.47%	0	0.00	3	3.00	21, 22, 23
Jan 2005	744	26.0	31.0	26.0	45.0	31	26	84%	84%	29.75	4	1.144	1.00%	43825.4	429050.7	24.96%	0.0	0.00	0.00%	24.96%	0	0.00	5	5.00	24
Feb 2005	672	28.0	28.0	27.0	72.0	28	27	96%	96%	30.84	4	1.142	1.15%	48017.8	470094.4	23.62%	0.0	0.00	0.00%	23.62%	0	0.00	1	1.00	25, 26
Mar 2005	744	31.0	31.0	31.0	103.0	31	31	100%	100%	35.85	4	1.156	1.20%	56194.8	550147.2	23.46%	0.0	0.00	0.00%	23.46%	0	0.00	0	0.00	26
Apr 2005	720	30.3	30.0	30.0	133.0	31	31	100%	100%	35.03	4	1.168	1.22%	53357.7	522372.4	24.14%	0.0	0.00	0.00%	24.14%	0	0.00	0	0.00	27
May 2005	744	31.1	31.0	31.0	164.0	31	31	100%	100%	36.05	4	1.163	1.21%	51959.7	508685.0	25.51%	0.0	0.00	0.00%	25.51%	0	0.00	0	0.00	28
Jun 2005	720	30.0	30.0	30.0	194.0	30	30	100%	100%	35.20	4	1.173	1.22%	53298.8	521795.6	24.29%	0.0	0.00	0.00%	24.29%	0	0.00	0	0.00	
Jul 2005	744	34.4	31.0	31.0	225.0	31	31	100%	100%	36.53	4	1.178	1.23%	53418.5	522966.9	25.15%	0.0	0.00	0.00%	25.15%	0	0.00	0	0.00	29
Aug 2005	744	31.0	31.0	31.0	256.0	31	31	100%	100%	36.80	4	1.187	1.24%	52529.0	514258.8	25.76%	0.0	0.00	0.00%	25.76%	0	0.00	0	0.00	
Sep 2005	720	30.0	30.0	30.0	286.0	30	30	100%	100%	34.86	4	1.162	1.21%	50238.7	491836.6	25.52%	0.0	0.00	0.00%	25.52%	0	0.00	0	0.00	
Oct 2005	744	31.0	31.0	31.0	317.0	31	31	100%	100%	32.55	4	1.050	1.09%	49467.8	484290.1	24.20%	0.0	0.00	0.00%	24.20%	0	0.00	0	0.00	
Nov 2005	720	29.0	30.0	29.0	346.0	29	29	97%	100%	28.45	4	0.981	0.99%	44104.6	431784.2	23.72%	0.0	0.00	0.00%	23.72%	1	1.00	0	0.00	30
Dec 2005	744	21.0	21.0	21.0	367.0	21	21	100%	100%	15.17	4	0.723	0.51%	29258.2	286438.1	19.07%	0.0	0.00	0.00%	19.07%	0	0.00	0	0.00	31

Running Totals	Total Time in Month	Total Run Time During Month	Total Run Time During Scheduled Test Periods			Total Attempted Starts	Total Actual Starts	Total Availability (Note 8)	Total Reliability	Total Energy Produced	Plant Capacity	Total Average Output (Note 11)	Total Capacity Factor (Note 12)	Fuel Usage		Average Electrical Efficiency (Note 13)	Total Thermal Heat Recovery	Heat Recovery Rate (Note 14)	Thermal Efficiency (Note 15)	Overall Efficiency (Note 16)	Total Number of Scheduled Outages	Total Scheduled Outage Hours	Total Number of Unscheduled Outages	Total Unscheduled Outage Hours
	(Hours)	(Hours)	(Hours) Scheduled	(Hours) Actual	(Hours) Cumulative			(%)	(%)	(kWe-hr)	(kW)	(kWe)	(%)	(liters)	(kJ, LHV)	(%, LHV)	(kJ)	(kWth)	(%, LHV)	(%, LHV)		(Hours)		(Hours)
	9288	372.1	377.0	367.0	367.0	378.0	369.0	97.3%	97.6%	408.75	4	1.114	1.10%	619626.8	6066146.4	24.26%	0.0	0.00	0.00%	24.26%	1	1.00	9	9.00

Notes:

1	Includes Scheduled Test Runs & Run Time During Loss of AC Grid		
2	Availability	=	Actual Run Time in Period / Scheduled Run Time in Period
3	Reliability	=	Actual Starts / Attempted Starts (Includes Test Starts & Loss of Grid Power Automatic Starts)
4	Average Output	=	Energy Produced / Run Time
5	Capacity Factor	=	Energy Produced / (Capacity * Time in Period)
6	Electrical Efficiency	=	Net Energy Produced / Fuel Usage
7	Heat Recovery Rate	=	Thermal Heat Recovery / Run Time
8	Thermal Efficiency	=	Thermal Heat Recovery / Fuel Usage
9	Overall Efficiency	=	Electrical Efficiency + Thermal Efficiency
10	Total Availability	=	Sum Total Run Time / Sum Total Hours in Period
11	Total Average Output	=	Total Energy Produced / Total Run Time
12	Total Capacity Factor	=	Total Energy Produced / (Total Capacity * Total Time in Period)
13	Avg. Electrical Efficiency	=	Total net energy produced / Total Fuel Usage
14	Avg. Heat Recovery Rate	=	Total Thermal Heat Recovery / Total Run Time
15	Avg. Thermal Efficiency	=	Total Thermal Heat Recovery / Total Fuel Usage
16	Avg. Overall Efficiency	=	Avg. Electrical Efficiency + Avg. Thermal Efficiency
17			
18			
19			
20			
21	Test program commissioned Dec 10		
22	12/12 AC outage at 22.37 for 14 minutes		
23	12/29 - 12/31 Out of fuel. Loss of 3 starts and 3 runs.		
24	1/1 - 1/5 Out of fuel. Loss of 5 starts and 5 runs.		
25	2/23 Out of fuel. Loss of 1 start and 1 run.		
26	Low electrical efficiency under investigation. Suspect hydrogen flow meter calibration error		
27	April 29: 17 min AC outage at 11.04. Fuel Cell Operational. Count run time in monthly totals.		
28	May 4: 6 min AC outage at 04.24. Fuel Cell Operational. Count run time in monthly totals.		
29	July 16: 3 hr 22 min AC outage at 17.02. Fuel Cell Operational. Count run time in monthly totals.		
30	November 29: Manually turned off PLC to allow special fuel delivery.		
31	Test program ended following December 21 run		

Appendix 4

Commissioning Procedures for the I-1000™ Fuel Cell & Outdoor Enclosure System

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SERVICE GUIDE SG04-15

8/30/04

Commissioning Procedures for the I-1000™ Fuel Cell & Outdoor Enclosure System

Objective: Evaluate fuel cell start-up and shut-down reliability and verification of alarm system functionality. Confirm fuel cell system contribution to power reliability at the site.

Commissioning Procedure 1

Check for hydrogen leaks at all hydrogen connections with handheld hydrogen detector (or commercially available soap solution can be used).
Suggested test points:

1. Cylinder connections
2. Manifold and hydrogen cabinet piping joints
3. Equipment cabinet piping joints
4. Fuel feed connection

NOTE: Commissioning Procedure 1 should also be performed when hydrogen cylinders are replaced.

Commissioning Procedure 2

Ensure DC bus power has been properly connected to the enclosure DC power terminals. Ensure AC circuit has been properly connected to the circuit breaker, disconnect, or junction box in the enclosure. Activate AC power to the fuel cell enclosure. Close the DC disconnect between the battery bank and the fuel cell enclosure. Verify correct DC voltage level at the enclosure DC power terminals.

Commissioning Procedure 3

Record hydrogen cylinder pressure gauges in Bay 1 (P_1) and Bay 2 (P_3).

Commissioning Procedure 4

Perform a manual fuel cell system start by setting fuel cell selector switch to "on" position. Verify fuel cell initiates start up and completes initialization (check for voltage on fuel cell LCD screen). Allow the fuel cell to run until voltage, current, and power levels on the LCD screen stabilizes. A fully charged battery bank will not demand a significant current flow. Therefore the power output of the fuel cell during this procedure probably be low.

Commissioning Procedure 5

Simulate a loss of AC power to the site.

1. Deactivate AC circuit breaker (located on the main panel in the equipment shelter).
2. Verify fuel cell initiates start up and completes initialization (check for voltage on fuel cell LCD screen).
3. Allow system to run to accumulate a total run time of at least 30 minutes.
4. Activate AC circuit breaker feeding power to the fuel cell system.
5. Verify fuel cell returns to standby state at fuel cell LCD screen.

Commissioning Procedure 6

The regulated pressure should be set between 25-75 psig. The optimal setting for fuel delivery pressure is 40-50 psig. By adjusting the regulated pressures so that one bay is 5-10 psig higher than the other side, hydrogen will flow out of the higher side only until those cylinders are exhausted. The system will then draw hydrogen from the other side allowing time to order and replace the depleted cylinders. The regulated pressure should be adjusted to 50 psig in Bay 1 and 40 psig in Bay 2 following initial installation of the cylinders or when they are replenished. During normal operation and post-run standby periods, the higher regulated pressure in Bay 1 will feedback to the regulated pressure gauge in Bay 2. As a result, the regulated pressure gauges on both sides will read the higher pressure (50 psig) even when correctly adjusted. Note that check valves are designed into the system to prevent gas flow from the high pressure side to the low pressure side. The regulated pressures in each bay can be correctly checked and adjusted with the following procedures.

1. Manually start the fuel cell by setting fuel cell selector switch to “on” position.
2. Verify fuel cell initiates start up and completes initialization (check for voltage on fuel cell LCD screen).
3. Record Bay 1 regulated pressure (P_2) and adjust to 50 psig if necessary.
4. Record Bay 2 regulated pressure (P_4) by closing the manual shutoff valve (located below the solenoid valve) in Bay 1 until the fuel cell(s) begin to draw hydrogen from Bay 2. When the pressure stabilizes, the regulated pressure set point can be correctly read and adjusted to 40 psig if necessary.
5. Following this verification of the lower regulated pressure set point, the manual shutoff valve in Bay 1 can be re-opened.
6. Continue running the fuel cell in manual mode with the selector switch in the “on” position and proceed to Commissioning Procedure 7.

Commissioning Procedure 7

1. Continue from Commissioning Procedure 6 with the fuel cell operating in manual mode. If off, manually start the fuel cell by setting fuel cell selector switch to “on” position and verify operation as before.
2. Remove one 650 series cartridge, confirm minor alarm activates.
3. Re-insert 650 series cartridge, confirm minor alarm clears.
4. Remove three 650 series cartridges, confirm major alarm activates.
5. Observe three attempts to restart followed by shutdown.
6. Re-insert the three 650 series cartridges, confirm major alarm clears.
7. Return fuel cell selector switch to “remote” position.

Commissioning Procedure 8

Inspect air filters (on enclosure door and at rear of fuel cell) and clean if necessary; clean per procedure in I-1000 Operating Manual.

Commissioning Procedure 9

Simulate DC Bus failure at the site (complete loss of rectifier/charger). {This was accomplished by setting the branch circuit breaker at the main power panel to “off” position for the rectifier/charger}.

1. Connect a digital multimeter to measure and record the DC Bus voltage (V_{dc1}).
2. Simulate DC Bus failure by disconnecting AC power to DC Bus system or alternatively shutting down the DC Bus system.
3. Monitor the DC Bus voltage and record the elapsed time (T_1) until DC Bus drops to fuel cell DC voltage start-up set point (V_{dc2}); trip point setting should be 25 Vdc.
4. Verify fuel cell initiates start-up when the DC voltage trip point is reached (check for voltage on fuel cell LCD screen).
5. Record the DC Bus voltage at time of fuel cell startup (V_{dc2}).
6. Record time from fuel cell initialization to fuel cell producing power (T_2); fuel cell is producing power when the fuel cell LCD screen indicates a positive current.
7. Record the maximum current produced by fuel cell (I_1) and time at which the maximum current occurs (T_3).
8. Initiate restoration from simulated DC Bus system failure.
9. Monitor the DC Bus voltage and record the elapsed time until fuel cell shuts down (T_4).
10. Record the DC Bus voltage at time of fuel cell shutdown (V_{dc3}).

Notes:

1. **Fuel cell selector switch should remain in "remote" position at all times (except during Commissioning Procedures 6 and 7).**
2. **For best performance, ReliOn recommends the I-1000 should not be subjected to repeated or short term on/off cycles beyond 10 cycles. If a period of repeat run cycles is planned, the "On" time for each run cycle should be a minimum of 30 minutes.**

Standards and Tolerances

Parameter	***Commissioning Procedure***	***Tolerance/Limit Initial Operating***
1. Bay 1 Cylinder Pressure (P_1)	1	500-2200 psi
2. Bay 1 Regulated Pressure (P_2)	1	50 psi
3. Bay 2 Cylinder Pressure (P_3)	1	500-2200 psi
4. Bay 2 Regulated Pressure (P_4)	1	40 psi
5. DC Bus Voltage (V_{dc1})	9	~ 27.3 Vdc
6. DC Bus Voltage (V_{dc2})	9	~ 25.0 Vdc
7. DC Bus Voltage (V_{dc3})	9	> 26.75 Vdc
8. Elapsed Time (T_1)	9	~ 1 minute
9. Elapsed Time (T_2)	9	~ 2 minutes
10. Elapsed Time (T_3)	9	~ 6 minutes
11. Elapsed Time (T_4)	9	~ 20 minutes
12. Maximum Current (I_1)	9	~ 17 amps